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ABSTRACT

This report addresses the widely held view that currently available literature in toxicology is inadequate in that there is a need to identify manpower deficiencies in this field and to suggest means to correct these deficiencies. It contains a list of specific recommendations including the organization of a working group, sponsored by the World Health Organization Regional Office for Europe, to discuss the design of model programs for teaching basic toxicology to physicians, scientists, and related specialists. (Author/RE)

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Manpower Development in Toxicology

Report on a WHO Consultation

Copenhagen
11–15 December 1978

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CONSULTATION ON MANPOWER DEVELOPMENT IN TOXICOLOGY

Copenhagen, 11 – 15 December 1978

1. INTRODUCTION

The purpose of the Consultation was to review manpower development in the field of toxicology, to discuss the present position in various countries, to predict needs, and to recommend a programme for training toxicologists.

The Consultation was opened by Dr Leo A. Kaprio, Director of the WHO Regional Office for Europe, who stressed that society had become increasingly dependent on the products of the chemical and allied industries. The range was wide including drugs, pesticides, synthetic fabrics and fertilizers. The majority of these have been extensively tested to assess their potential toxic effects but some have either not been tested at all or, at best, inadequately. There is now a growing awareness of, and concern for, the potential adverse effects on health that such materials may have. In particular, concern is expressed regarding the consequences of long-term exposure to low doses of chemicals.

Countries are beginning to introduce legislation to ensure better control over the manufacture, use and disposal of chemicals. No system of legislative control, however, is practicable unless adequate resources exist for its implementation and enforcement. These resources include *inter alia* those in industry, in commercial toxicology laboratories, in academic institutions and in regulatory bodies responsible for assessing and evaluating information from industry and elsewhere.

As there is a widely held view that currently available resources in toxicology are inadequate, there was a need to make an accurate assessment of how large the manpower deficiencies are, to define areas of particular shortage and suggest means by which such deficiencies can be made good as quickly as possible.

Mr J.I. Waddington, Director, Promotion of Environmental Health, WHO Regional Office for Europe, then referred to WHO's long-standing involvement in programmes concerning the potential toxicity of chemicals, in technical cooperation and in dealing with chemical emergencies. In addition, following resolutions of the Thirtieth and Thirty-first World Health Assemblies, an International Programme on Chemical Safety is now being developed

and will be discussed by the WHO Executive Board at its next meeting in January 1979. An important element of this comprehensive programme is the development of trained manpower. The deliberations of the present Consultation were therefore both timely and of considerable importance.

Dr E. Poulsen was elected Chairman and Dr F.A. Fairweather Rapporteur.

2. THE EXISTING SITUATION IN THE FIELD OF TOXICOLOGY

Bulgaria

It was stated that in Bulgaria, at the present time, approximately 75 people were engaged in toxicological research, the majority of whom worked in the Institute of Environmental and Occupational Health in Sofia. The main purpose of the work of this Institute concerned the potential long-term effects of industrial and agricultural chemicals. Metabolic studies are also undertaken, together with investigations to determine maximum allowable concentrations of chemical pollutants in air, soil and water.

The Institute also carries out epidemiological studies and prepares literature surveys to assist the registration of pesticides and other toxic compounds. Some toxicological research is also carried out in the Faculties of Medicine and Pharmacy.

While most toxicologists are medically qualified, biologists, biochemists, microbiologists and epidemiologists are also involved in toxicological studies. This team works in close collaboration with mathematicians and statisticians.

In the practice of environmental and occupational health, and especially in sanitary-epidemiological work, the medical toxicologists work in close association with the toxicological chemists.

Toxicology is recognized in Bulgaria as an additional specialty for physicians and involves several years' postgraduate study.

Denmark

It was reported that in Denmark, one of the few laboratories with specific responsibility for toxicological research was the Institute of Toxicology (part of the Danish Food Institute). Until recently, medical doctors have shown little interest in the subject which remains only a small part of the medical curriculum. As a consequence, both the Institute, and particularly the pharmaceutical industry, have found difficulty in attracting medically-qualified personnel to toxicological work and have relied on veterinarians and

pharmacologists – a reflection of the existence of a Chair in Pharmacology and Toxicology in the Veterinary School and of the inclusion of some toxicology training in pharmacology courses.

Draft legislation at present under discussion and the development of a new Institute of the Working Environment will both create a further demand for trained toxicologists. While there are as yet no plans for formal training in the subject, this will almost certainly be at postgraduate rather than undergraduate level. Where such training is offered to nonmedical graduates, the need for additional instruction in pathology was stressed. It was argued that where possible, those engaged in regulatory activities related to toxicology should have had previous experience in the subject at a practical level. Without this background, there was the danger that people might consider a short course of training sufficient to make them knowledgeable in all aspects of toxicology.

Finland

In discussion on the situation in the Nordic countries, it was reported that Finland has some 15 units – mainly university departments or institutes – engaged in research or training in toxicology. Of these, the largest is the Institute of Occupational Health which contributes 60% of the approximately 100 annual publications on industrial and environmental toxicology. Two categories of experts are recognized:

(1) those professional toxicologists who work in toxicological research on a full-time basis, but also assist in the teaching of students – they number approximately 50 and in nearly all cases are medically qualified;

(2) those experts in other disciplines who need some knowledge of toxicology as part of their professional profiles – the latter number about 1 250 and include those employed in occupational and environmental health, industry, administration and university teaching.

Although a new Chair of Toxicology has recently been created and some training in toxicology is given as part of courses in pharmacology, formal training in the subject, and in appropriate research methodology, is normally at postgraduate level and is undertaken largely by the Institute of Occupational Health. The Institute also runs courses designed for occupational health workers, nurses, engineers and laboratory technicians.

With regard to international courses, the Institute organizes each year a postgraduate training course in toxicology in Finland, and has been active in running related courses in developing countries such as Tanzania and Zambia.

Federal Republic of Germany

In the Federal Republic of Germany, specific interest in resources in toxicology dates from 1972 when a group of people from some of the

German-speaking countries met to discuss the problem. A study was subsequently undertaken to review the present situation, to assess future demand and to gather ideas on the development of the subject. The findings of the study were published in Denkschrift Toxikologie.[a]

Toxicology has been brought into focus because of the interest of the general public and the increasing concern about long-term exposure to low doses of chemicals. There is also the growing realization that health risks linked to the use of pesticides, food additives, industrial chemicals and pollution of air, soil and water are less easy to control than is the case with the use of drugs. In addition, the effective implementation of new legislation on toxicological problems is hampered by the shortage of toxicologists.

As in Italy, pharmacology and toxicology have historically been united, mostly in the same university department. During the last 15 years, however, some independent departments or institutes for toxicology have been established, distinct from the existing departments of pharmacology/toxicology.

Outside the universities, toxicological work is carried out in laboratories belonging to the chemical and pharmaceutical industries or in institutes responsible to the public health authorities. However, the available resources are by no means sufficient to cope with all the new tasks, especially in the field of environmental protection.

To date toxicologists in the Federal Republic have required a medical qualification, with a further five years' postgraduate experience in toxicology and pharmacology. Because demand is expanding rapidly, however, it is no longer possible to rely solely on recruitment via medicine, and therefore graduates in biology, chemistry, biochemistry, pharmacy and physics are being regarded as indispensable. Such recruits will receive four to six years' training in toxicology, with some background medicine. Additional experience in industry is also recognized by the German Pharmacology Society.

There are no plans, as yet, for formal government recognition of toxicologists in the Federal Republic of Germany.

Italy

In Italy, pharmacology and toxicology have historically been combined in the same department in universities and various institutions. During the last decade, however, some distinction has been made in the universities and both industrial and forensic toxicology are recognized as discrete subjects.

Toxicological resources – both laboratories and trained personnel – are found in the pharmaceutical and chemical industries, and outweigh those in the universities. A central public health organization also exists to deal with related problems, but there is, on the whole, a general lack of expertise.

[a] **Bär, F. et al.** *Denkschrift toxikologie*. Bonn-Bad Godesberg, Deutsche Forschungsgemeinschaft, 1975.

The frequency with which problems related to chemicals and environmental health arise was cited to illustrate the urgent need to train manpower in this field and to seek expert guidance.

A new chair of industrial toxicology has been envisaged, but a more basic approach to the subject is needed. Laboratories with adequately trained personnel are needed to carry out short- and long-term toxicity tests, with particular emphasis on carcinogenicity and teratogenicity. Recent events in Italy had demonstrated that epidemiologists should play a much greater role in aiding the toxicologist in his appraisal of various situations. Further, while the involvement of chemists, biochemists and biologists in toxicological problems was welcome, they clearly needed guidance from both medical and public health authorities.

In summary, there was a marked lack of expertise in toxicological matters in Italy, which required an expeditious solution.

Sweden

It was reported that in Sweden the number of people engaged in toxicological research was approximately twice that in Finland. Several units have active research programmes, particularly in the field of industrial toxicology and occupational health. These include the Karolinska Institute, the National Board of Labour Protection and the University of Lund, where a Chair of Toxicology was established in 1977.

The Swedish National Food Administration (which responds to the Ministry of Agriculture) is serviced by a toxicology laboratory carrying out food research. The National Environment Protection Board is concerned with problems related to the general environment and, for example, grants licences for permission to use certain hazardous substances. While one task of the Board is the implementation of the Environment Act of 1969, the available resources for enforcement are inadequate.

Union of Soviet Socialist Republics

In the USSR, toxicology has a wide meaning and its importance is reflected in the number of institutes involved in the science. There are 84 medical institutes preparing people for medicine, 28 of which have a Hygiene Faculty, dealing with environmental hazards. Research institutes dealing with occupational health number 16, while a further 6 are concerned with environmental health and 2 with nutrition. All these have laboratory facilities and carry out experimental work on a variety of compounds. Carcinogenicity assessments are the particular concern of the Institute of Oncology, while the Institute of Ecological Toxicology gives special attention to the potential adverse effects of chemicals on ecosystems. The majority of these institutes

offer special postgraduate training courses. Postgraduate training facilities for certain aspects of toxicology are also available at the Institute of Toxicology in Kiev.

The main responsibility for environmental health matters lies with the Ministry of Health, but other ministries are also involved. Thus laboratories responding to the Ministry of Technology are carrying out increasing amounts of basic toxicological work, particularly on industrial chemicals. Plans to develop such resources require the provision of more trained toxicologists.

Those working in the field of toxicology typically have qualifications in medicine, veterinary medicine or one of the biological sciences. It is customary, however, for the final recommendations concerning permissible levels of pollutants or hygienic standards to be made by medically qualified specialists, as these limits are based solely on health considerations.

United Kingdom

In the United Kingdom, attitudes to toxicology have changed noticeably over the last 5 years, and particularly in the last 18 months. Toxicologists are employed in 3 main areas. The first group, by far the largest, is found in industry. Experienced medical and nonmedical graduates work in the chemical, pesticide, pharmaceutical and food producing industries. A great deal of toxicological testing is carried out within the various industrial laboratories, but private contract laboratories also fulfil an important role.

Toxicologists are also employed in some universities, such as those of Surrey and London (Hammersmith Hospital), which offer special postgraduate training courses, and in research institutes. The Medical Research Council, for example, employs experienced toxicologists, but the emphasis of their work is on basic mechanisms of toxicology, rather than routine testing.

Finally, a minority of toxicologists are employed in government service for assessment of experimental data on drugs, food additives, insecticides, industrial chemicals, etc.: they include both medical and nonmedical graduates. Particular difficulties have been experienced in recruitment to this area.

Recent interest by the Royal College of Pathologists, and the establishment of a Toxicology Laboratory by the Department of Health and Social Security at St Bartholomew's Hospital, London, have led to improved possibilities for postgraduate training and examinations in toxicology. Two types of training courses are at present envisaged: one for those with basic qualifications in human or veterinary medicine, the other for science graduates. Both will entail approximately five years' study, with particular emphasis given to comparative pathology.

Further assistance to government departments is available from a series of expert committees, covering areas such as general toxicity, carcinogenicity, mutagenicity and environmental health. Such committees are chaired by eminent individuals from academic institutions.

In the evaluation of health hazards and risks, it was stated that medically qualified personnel should play a major role.

United States of America

It was reported that in the United States, a series of factors have combined to intensify interest in expanding the training of toxicologists. Among these have been a growing concern, both among the public and in Congress, with potential health hazards from environmental chemicals, and the significant volume of new relevant legislation, particularly the Toxic Substances Control Act. The matter has been under active discussion and development for several years.

It has been estimated that there are approximately 5000–6000 practising toxicologists in the United States. These individuals have diverse education backgrounds but, typically, include postdoctoral graduates in pharmacology, physiology, biochemistry and, to a limited extent, medicine. Characteristic of this group, however, is practical experience developed over many years. The principal employers of professional toxicologists in the United States are government agencies and private industry, including contract laboratories. In this context, the National Institute of Environmental Health Services will have an increasingly important role through its involvement in a new National Toxicology Programme which gives the Institute responsibility for some of the resources of other units such as the National Cancer Institute and the National Centre for Toxicological Research. The creation of this Programme and the implementation of the Toxic Substances Control Act are creating considerable demand for toxicologists. There is a belief that moves to upgrade the professional status and salaries of toxicologists, particularly in government service, will attract more high-calibre people to the field.

Formal training in toxicology is likely to remain at the postgraduate or postdoctoral levels. In the latter instance, three-year fellowships are available for those wishing to reorientate their careers or to participate in research programmes in toxicology institutes. Accreditation of professional toxicologists by the Society of Toxicology is likely within the next two years.

3. THE CONCEPT OF TOXICOLOGY

With ever-growing worldwide industrialization, increasing dependence is being placed upon chemical products of all kinds. Modern food production, for example, depends on the widespread use of pesticides, fertilizers and animal husbandry products. In convenience foods, the increased use of additives has become apparent. Chemicals are also used in a wide range of

household products such as detergents, cleaners, polishers, cosmetics, toiletry products and other consumer goods. The appearance of plastics in everything from food packaging and toys, to cars and building materials is further proof of current dependence on chemicals. Since such materials may be synthesized in one country, and then exported to many parts of the world, the possibility of their release to the environment is clear.

The Consultation recognized that, in effect, the community at large comes into contact with these chemicals. Some persons in particular environments, e.g., the working environment, may be exposed to higher concentrations than those to which the general population is exposed. The chemicals contained in various products may have direct effects on health or may find their way by various routes into air, soil or water where they may damage animal or plant life or, as pollutants, they may simply inhibit enjoyment of the environment. With growing public awareness that some of these chemicals are potentially dangerous, it is imperative to consider means by which their adverse effects may be assessed and by which the safest of particular compounds may be selected for use. The need to establish systems of assessment and surveillance of these compounds is worldwide.

The difficulty lies not in the acceptance of the general philosophy of human health protection, but in the convincing presentation of the findings on safety and risk to human health arising from defined pollutants. At present insidious adverse effects, such as carcinogenic, teratogenic or mutagenic effects, that may result from long-term exposure to a pollutant or pollutants, are of greater concern than the acute or subacute adverse effects.

Since it is the task of the professional toxicologist to investigate and evaluate these effects and as the field of study is rapidly expanding in size, scope and methodology, the Consultation wished to record its understanding of the terms "toxicology" and "a toxicologist". In so doing, it excluded from consideration both forensic toxicology (the science related to determining causes of death in cases of poisoning) and clinical toxicology (as applied to the clinical assessment of drug efficacy/toxicity under controlled conditions).

It was agreed that toxicology is a distinct subject concerned with the detrimental effects of chemicals on living organisms. It is concerned primarily with effects on the human organism, but includes potential adverse effects on all animals and plants. The science is concerned with reducing the risk associated with exposure to chemical substances to a tolerable level.

Modern toxicology is a highly complex multidisciplinary field drawing together the individual expertise of medical, veterinary and science graduates.

Such individuals may study the basic mechanisms underlying the effects observed and the biochemistry associated with abnormal cellular processes. The pharmacokinetics may be elucidated, and assessment of risk from both animal experiments and epidemiological studies may be carried out. The toxicological influence on ecosystems including plants may be studied and both the analytical and quantitative aspects of toxicology may be considered.

A toxicologist is thus one who has expert knowledge in several toxicological fields, as defined, and who uses this expertise to assess the hazards of chemicals to human, animal or plant life.

In accepting this definition, the Consultation gave considerable weight to the need for medically qualified toxicologists (particularly for the assessment of the significance of experimental data for man), but wished to include those nonmedically qualified personnel whose contribution to the multidisciplinary subject of toxicology was considered essential.

4. PREDICTION OF MANPOWER NEEDS

It has become evident, from the Toxic Substances Control Act in the United States, the Health and Safety at Work Act in the United Kingdom and other new Acts being prepared, that new environmental health legislation has created major new demands for toxicological studies and for a large pool of professionally trained toxicologists capable of generating and interpreting such studies. In predicting future resource needs, however, the Consultation recognized the dangers of overestimation, as the production of well qualified toxicologists is costly.

It was accepted that a logical step-by-step process was essential in assessing the toxicity or potential toxicity of a chemical. The need to assess both the exposure and effect of the compound was also appreciated.

The Consultation discussed at length the complex issue of balancing perceived need for additional toxicologists against actual demand. Certain criteria should be borne in mind when deciding the number of toxicologists needed within the various countries. These included the social needs of the community, its size, the pattern of trade, e.g., the number of chemicals in use or being introduced, existing or developing legislation or the effect that regulations in other countries or organizations might have on a community. Activities in the European Economic Community, the Council for Mutual Economic Assistance and United States regulatory agencies were cited as examples of the latter category.

The Consultation agreed that when such factors had been considered it was necessary for governments not only to invest in training programmes for toxicologists, but also to ensure that adequate administrative arrangements exist to deal with the components of a systematic evaluation programme of various pollutants, whether in food, air, water or soil. Such a programme might include:

(a) identification of pollutants;

(b) assessment of health effects of environmental pollutants;

(c) promotion of research on health effects of environmental pollution;

(d) establishment and enforcement of environmental quality standards necessary to protect public health, including standards for the quality of water used for drinking, other domestic purposes and recreation; ambient air quality standards; maximum permissible limits for occupational exposure to toxic chemicals; standards for the exposure of man to various forms of radiation, noise, and other physical hazards; and maximum daily intakes and tolerances for toxic substances in food;

(e) evaluation of environmental health projects;

(f) participation in licensing procedures;

(g) inspection of factories and other workplaces;

(h) control of the use of toxic substances in agriculture and in households;

(i) provision of guidelines for the disposal of toxic solid wastes;

(j) monitoring of environmental influences on health;

(k) monitoring of air pollution in urban and industrial areas and of the quality of community water supplies, sources of drinking-water, and of recreational waters;

(l) development and use of public health criteria for the siting of potential sources, such as power plants or industries, and the establishment of protective zones;

(m) training of health workers in pollution control;

(n) provision of guidance in all aspects of pollution control that may have public health implications.

Where legislation related to the control of environmental pollutants is enacted, the Consultation strongly asserted that its quality depended on the knowledge of administrators and their toxicological advisers. It stressed that "decision makers" or advisers to ministers must have a scientific background with a strong toxicological component or that they should have taken a course in the basic principles of toxicology, and be constantly advised by professional toxicologists.

The multidisciplinary nature of the subject lends itself naturally to the concept of a "toxicological team". The Consultation agreed that in addition to medical, veterinary and biological science graduates, those qualified in disciplines such as microbiology, immunology and epidemiology should be encouraged to participate.

Concern was expressed at the time it would take to produce the number of toxicologists required, and to blend them into the various integrated functioning units that are necessary. In some cases, this could take three to five years, in others a decade.

In considering approaches to the problem, however, the Consultation felt it necessary to:

(1) *Define the knowledge, skills and attitude of the professional toxicologist*. The fundamental criteria should be knowledge of the subject in depth. Experience in experimental studies was considered essential. The attitudes necessary for assessment of data should be those of neutrality, impartiality and independence, the ultimate objective being the protection of human health.

(2) *Define the education objectives*. While these may be defined in a number of ways, and appropriate methods devised for measuring their attainment, the foundation for this specific and highly specialized type of training must be a broad basic education. A particular challenge is the need to provide different levels of training in toxicology to produce both professionals who will use their skills daily, and also those who must be familiar with the basic principles of the subject, but who will use this knowledge sporadically.

The Consultation was unanimous that this type of specialization should be undertaken at the postdoctoral level. Course content should include:

(a) general test methods used in toxicological investigations;

(b) mechanisms of action and behavioural studies;

(c) biochemistry of foreign substances and their subcellular effects;

(d) pathology and histopathology of animals;

(e) mutagenicity testing;

(f) testing for effects on reproduction;

(g) chemical carcinogenicity;

(h) allergy to foreign substances;

(i) clinical toxicology;

(j) epidemiology and statistics.

(3) *Plan a study programme*. The Consultation agreed that individual countries may wish to follow their own programmes in this respect. Some

countries may opt for short- or long-term teaching courses with specialization in certain subjects, such as carcinogenicity testing or teratology. On the other hand, universities may develop training programmes on the "module system", in which participants may select those elements most suited to their needs. Each approach had its advantages, provided that intellectual versatility, open-mindedness and continuing education in new techniques were encouraged.

(4) *Provide proof of achievement of goals*. Discussion here related to provisions, such as examinations or the preparation of doctoral theses, to demonstrate achievement in toxicology training courses. The Consultation felt it inappropriate to lay down any international standards on this matter, but left the decision to individual countries. A logical training sequence, with research experience was necessary, but in the end only the country itself could be the judge of the system as it related to the toxicologist's performance or expertise. It was strongly emphasized that with a constantly developing subject such as toxicology, there was a continuing need to keep abreast of new developments. With five or more years' postgraduate experience, however, a specialist status could be recognized.

Following this long and detailed discussion, some countries were able to give a preliminary assessment of the probable numbers of toxicologists they needed over the next few years. Thus, on an annual basis, the following estimates were given:

Finland	7 – 10 toxicologists
Federal Republic of Germany	50 toxicologists
United Kingdom	40 – 50 toxicologists
United States of America	150 – 200 toxicologists

5. EXISTING TRAINING FACILITIES

Within the various countries represented, the Consultation recognized three distinct resources at present engaged in training toxicologists. The first of these was the universities, within which faculties of human and veterinary medicine, biology, agriculture and chemistry were providing training programmes. It was agreed, however, that there was an urgent need to create more schools to cope with the problem. It was emphasized that the educational level should be postgraduate or postdoctoral, and that courses should be of not less than three years' duration. Where possible a multidisciplinary approach should be followed for general training with specialization in particular aspects of the subject being encouraged.

In this context, institutes of occupational health and workshop groups in toxicology are currently assisting in the toxicological training of medical students and environmental hygienists in Finland, while in the USSR some 16 institutes of occupational health, 28 medical institutes and 16 environmental and food institutes offer relevant training. In the USA it was reported that at least 20 programmes, sited mainly in environmental medical schools, pathology and biochemistry departments and veterinary schools, are producing high-calibre postdoctoral toxicologists.

The second source of toxicologists at the moment is industry. In Denmark and the United Kingdom, on-the-job training is considered an essential feature of education, and the Consultation agreed that this should be encouraged, provided the training was of a multidisciplinary nature and was accompanied by day-release schemes for extra tuition, or attendance at other specialized courses. In this context, the Consultation noted that the International Agency for Research on Cancer has a scheme for research training fellowships, with an annual budget of $ 250 000, and that it was encouraging extra training in the field of chemical carcinogenesis.

Finally, it was reported that some governments have introduced training schemes for toxicologists. For example, a programme has been established in the United Kingdom which gives particular emphasis to training in comparative histopathology. The Consultation considered this to be important as specialists in this aspect of toxicology are in notably short supply.

An encouraging note is that some of the above schemes are already leading to international collaboration and exchange of ideas.

6. REQUIRED TRAINING FACILITIES

The Consultation agreed that people are living in an era in which enormous progress is being made in catering for the needs of man and his society, but unfortunately many of the important decisions on limiting damage to human health by chemicals are being taken by the uninitiated. Thus a well developed scheme of training, with a sound career structure, is essential so that a critical review of toxicological testing procedures and their application to the protection of human health may be forthcoming. The challenge in modern toxicology is to develop and evaluate research and testing programmes which are truly predictive of the potential of chemicals to produce injury to health, under a variety of exposure conditions.

Since governments have enacted legislation with the intention of protecting human health — laws which in effect have created the need for toxicologists — they must be told of their responsibilities for long-term training of this required manpower. There is the further need to create suitable

career structures, particularly within government service, to attract high-calibre candidates. By way of comparison, it was stated that within industry, toxicologists are attracted by good salaries, secure funding of research, continuity of management planning, respected status within an organization, and the possibility of contributing to the welfare of society.

It was agreed that existing training resources – whether in universities, industry or government agencies – should be actively developed. The Consultation felt that courses in general toxicology should be supplemented by specialized training in, for example, food, industrial or pesticide toxicology. An interdisciplinary approach was considered essential, whatever the nature of a specific course.

The Consultation recognized the advantages of a national centre embracing all the necessary disciplines, but appreciated that practical constraints might dictate the need to use a "building block" system for training, in which the expertise in various departments or institutes could be combined to offer a more diverse range of education and activities than could be found in any single department.

In smaller countries, the combination of domestic courses with appropriate internationally recognized special courses should be encouraged. The Consultation particularly stressed that WHO had a vital role to play in this area and thought it essential that within the European Region, a survey should be undertaken of institutes capable of offering training at the post-graduate level. The preparation of lists of names of national experts in the field of toxicology would be most helpful.

The Consultation considered the retraining of personnel with post-doctoral qualifications in other fields and agreed that this should be encouraged, particularly with respect to pharmacologists and biochemists. It was again emphasized that administrators working in environmental health should be familiar with the principles of the tests that were carried out and with their predictive value. Medically qualified personnel working in occupational health should also receive training in the basic principles of toxicology. This would include the concept of dose-response relationships, the major adverse reactions that could occur in man, species variation in effects (particularly between animals and man), pharmacokinetics, and the primary elements of epidemiology.

With regard to other groups, there was agreement that chemists, chemical engineers, laboratory and animal technicians should all receive training, according to their needs. This would considerably improve the ability of such individuals to work constructively with other members of the toxicological team when necessary.

Finally, while the Consultation agreed that there was an overall shortage of toxicologists, it considered that certain neglected areas of the subject needed special attention, in terms of the provision of training courses. These

include inhalational toxicology, behavioural toxicology, epidemiology, neuro- and cardiovascular toxicology, teratology, the study of allergic reactions and comparative histopathology.

7. INTERNATIONAL COLLABORATION

In discussing the subject of international collaboration, the Consultation agreed that there was an urgent need to promote international recognition of toxicology as an independent science, with wider understanding of the training methods and modules used in the various Member States, so that essential reciprocal recognition and acceptance of this training might be achieved.

In response to resolution WHA30.47, with its call for the development of manpower, there was a need to prepare, in the European Region, a list of national experts in specific disciplines, to foster full cooperation and to make the best use of this important manpower resource.

It was agreed that the accent must be on postgraduate training and that potential toxicologists should be encouraged to pursue a broad course of training in the subject, with subsequent specialization where necessary, rather than to enter narrow or restricted fields of study. Where necessary, Member States should help others in the provision of training facilities, courses and exchange of experienced personnel in order to produce specialists of the highest calibre.

The Consultation felt that its meetings had been held at an expedient time and recommended that the views expressed in its report should be borne in mind with respect to manpower development for the proposed International Chemical Safety Programme.

8. CONCLUSIONS

In the Region, and indeed worldwide, there is a dearth of experienced professional toxicologists, particularly those capable of evaluating data in terms of their practical significance to man. It is also important that administrators and auxiliary personnel working with these experts have some experience and basic knowledge of the science.

There is a diversity both of practice in the training of toxicologists and the curricula followed. However, this should not stand in the way of developing an integrated approach to the topic. Lessons could be drawn from the experiences of each Member State, to make a more rapid advance in the solution of mutual manpower problems.

WHO could play an active role in explaining to governments the need to employ properly trained and experienced toxicologists in any assessment of experimental and epidemiological data. Furthermore, all the recommendations given below should be carefully considered, and taken into account in developing the proposed International Chemical Safety programme.

9. RECOMMENDATIONS

1. To attract high-quality graduates to the field of toxicology, governments should:

   (a) recognize that toxicology is a specialist subject in its own right;

   (b) create sound career structures for toxicologists, with salary levels commensurate with those of professionals in more established fields and, particularly, comparable to those in industry.

2. The final assessment of data should be carried out by multidisciplinary teams, including medical, veterinary and science graduates experienced in toxicology, with priority given to human health criteria.

3. While there is general agreement on the shortage of toxicologists, a distinction should be made between "perceived need" and "actual demand" for such professional expertise. For this purpose, national studies of the present and anticipated situation should be carried out in the Member States to clarify the quantitative estimates of need and assess the patterns. Emphasis should be given to such areas as behavioural toxicology, immunology, comparative pathology, and epidemiology. Countries should be encouraged to make a concerted effort to predict the number of new chemicals which will be manufactured and ultimately released into the environment, so that a realistic estimate may be made of the toxicological manpower required within the next few decades.

4. Harmonization of curricula in Member States is needed to guarantee the production of toxicologists with comparable qualifications in the various WHO regions. Specialized curricula should also be developed for suitable postgraduate and postdoctoral training of toxicologists.

5. Every country should integrate the resources of all its institutions to develop the necessary training schemes. A coordinating institution at national level should be recognized, but in certain situations where one does not exist as such, an institution serving several countries could be used.

6. Countries which cannot themselves organize all parts of the training should be encouraged through WHO or by other arrangements to use international training facilities or centres in other Member States. International collaboration in producing adequate manpower in this field is strongly recommended.

7. To avoid unnecessary duplication of effort, with consequent uneconomic use of manpower, the possibility of international collaboration in toxicological testing should be explored.

8. Within industrial organizations, encouragement should be given for on-the-job training, accompanied by attendance at suitably designed toxicological courses to provide broad training and knowledge within the discipline. Governments should be encouraged to approve training courses of other countries, and there should be a mutual recognition of qualifications.

9. Attention should be paid to meeting the shortage of ecotoxicologists and developing widely accepted methods to assess the effects of chemicals on non-human fauna and flora in the environment.

10. WHO could undertake a survey of institutes in the Region which can provide training in toxicology at postgraduate or postdoctoral level. Such a survey should in particular identify institutes able to offer international courses, and should indicate the specialty of each institute.

11. WHO could prepare for the Region a list of national experts in various fields of toxicology and ensure that appropriate groups are in contact with each other. Such arrangements would ensure that regional philosophies are shared and common opinions, where appropriate, reached on particular problems such as nitrosamines, nitrites and saccharin.

12. The Regional Office should convene, as soon as possible, a working group to discuss the design of model programmes for teaching basic toxicology to physicians, postgraduate scientists and related specialists. The group would also have to discuss in broad terms ways in which graduates in given disciplines could be retrained to become effective toxicologists. Attention should also be paid to defining criteria for the estimation of future needs for toxicologists.

13. WHO could promote further development of training facilities in various countries, stressing the need for a multidisciplinary work profile.

14. Encouragement by WHO for the use of mathematics and statistics in toxicological research would stimulate the development of mathematical

models for prediction and calculation of possible safe levels of toxicity and exposure. Utilization of toxicokinetics is essential, and studies of long-term effects on the central nervous and cardiovascular systems are of paramount importance.

15. As a basis for education in the principles of toxicology, encouragement should be given for use of the WHO publication "Environmental health criteria. 6: Principles and methods for evaluating the toxicity of chemicals".[a]

[a] Published under the joint sponsorship of the United Nations Environment Programme and the World Health Organization, Geneva, 1978.

Annex

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